Surficial geology, soils and permafrost of the northern Dawson Range

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ABSTRACT

New mineral discoveries in the Dawson Range have been heavily supported by soil geochemistry. The use of soil augers to penetrate through loess-rich units and into locally derived weathered bedrock has been important in the successful application of this technique. To assist the mineral exploration industry, we characterized the surficial geology, soils and permafrost of the northern Dawson Range. Mapping indicated that widespread loess is present in the study area and the thickest deposits are located in basins on the south side of the Dawson Range near the Donjek and White rivers. A mantle of weathered bedrock covers virtually the entire landscape. The texture of fluvial deposits is affected by stream order and base level changes along the Yukon River. By understanding the effects of slope, aspect, elevation and permafrost processes on surficial materials, a landscape model can be developed that will facilitate geochemical exploration and mineral development in the region.

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INTRODUCTION

Recent surficial mapping field work in the northern Dawson Range concludes a three-year surficial mapping project conducted in the Stevenson Ridge map area (NTS 115J; Fig. 1). The objective of mapping the northern Dawson Range was to provide baseline surficial geology information that is applicable to mineral exploration, mineral development, and ecological land classifications. Much of the Dawson Range is underlain by weathered bedrock, so it is assumed that this terrain would be suitable for exploration using the geochemistry of surficial deposits. In places this is true; however, the periglacial climate of the region, and the widespread Pleistocene eolian deposits, complicate both the collection and interpretation of geochemical data. Furthermore, there will be terrain challenges for mineral development such as building on relatively warm permafrost and dealing with a shortage of high-quality aggregate resources for construction of infrastructure. This paper provides a summary of surficial geology investigations during the 2010 field season.

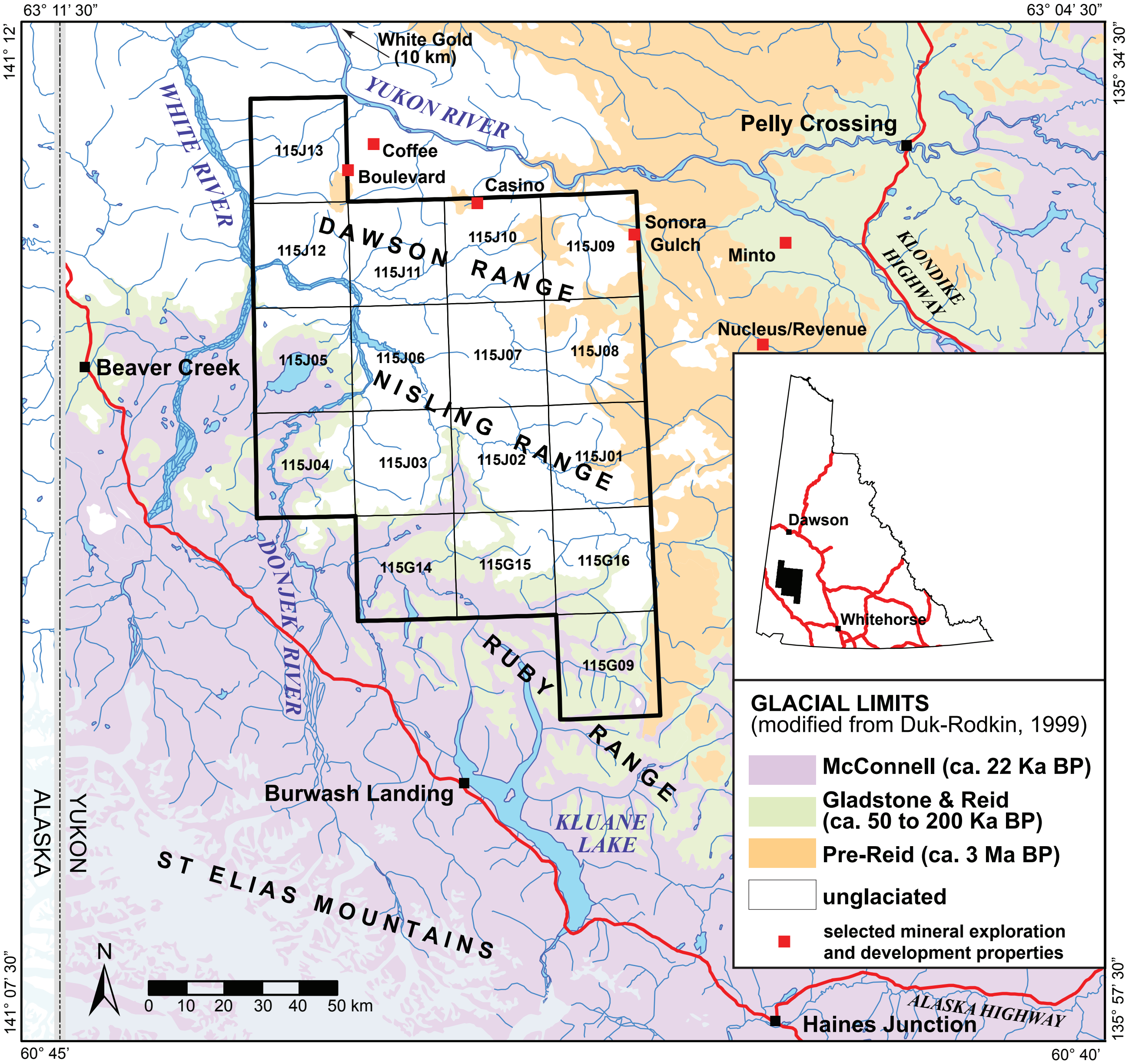

Figure 1. *Location of the Stevenson Ridge (115J) and northern Kluane (115G) study area relative to the glacial limits. The focus for the 2010 field season included 1:50 000-scale map sheets 115J/09-13.*

SETTING

PHYSIOGRAPHY, DRAINAGE AND CLIMATE

The Dawson Range is a northwest-trending mountain range in western Yukon that stretches for over 100 km (Fig. 1). The 2010 study area focused on the northwestern extent of the range in map sheets 115J/09 – 13 (Figs. 1 and 2). With the exception of glaciated massifs, such as Mount Cockfield (1905 m a.s.l.) and Apex Mountain (2022 m a.s.l.), the study area consists mostly of broad, rounded, unglaciated summits that have elevations near 1370 m a.s.l. (Fig. 2). Valley morphology differs depending on proximity to the Yukon River. Streams that flow directly into the Yukon River have experienced a drop in base level, potentially associated with reversal of the Yukon River from a south- to a north-flowing drainage during the early Pleistocene. This Pleistocene base-level change has resulted in deeper incision of third-order reaches of Yukon River tributaries in the Dawson Range. Stream order is defined as a method of classifying waterways, whereby first order streams are the smallest headwater streams. Where two first-order streams meet, a second-order stream is created (Strahler, 1952). Most tributaries flowing into the Yukon River from the Dawson Range are third or fourth-order drainages. Evidence of the base-level change is most obvious in larger valleys, such as Independence and Carlisle creeks (Fig. 2), where fluvial terraces are preserved near the confluence with the Yukon River. Streams that flow into the Donjek and White rivers however, did not undergo a significant change in base level; in fact, the base levels have possibly risen due to the effects of glaciation in the Wellesley Lake area. As a result, the third and fourth-order streams on the south side of the Dawson Range have wide, low-gradient floodplains.

The climate of the region is described as cold and semi-arid. The mean annual temperature is between -4 and -8°C and the mean annual precipitation is 300 mm (Smith *et al.*, 2004).

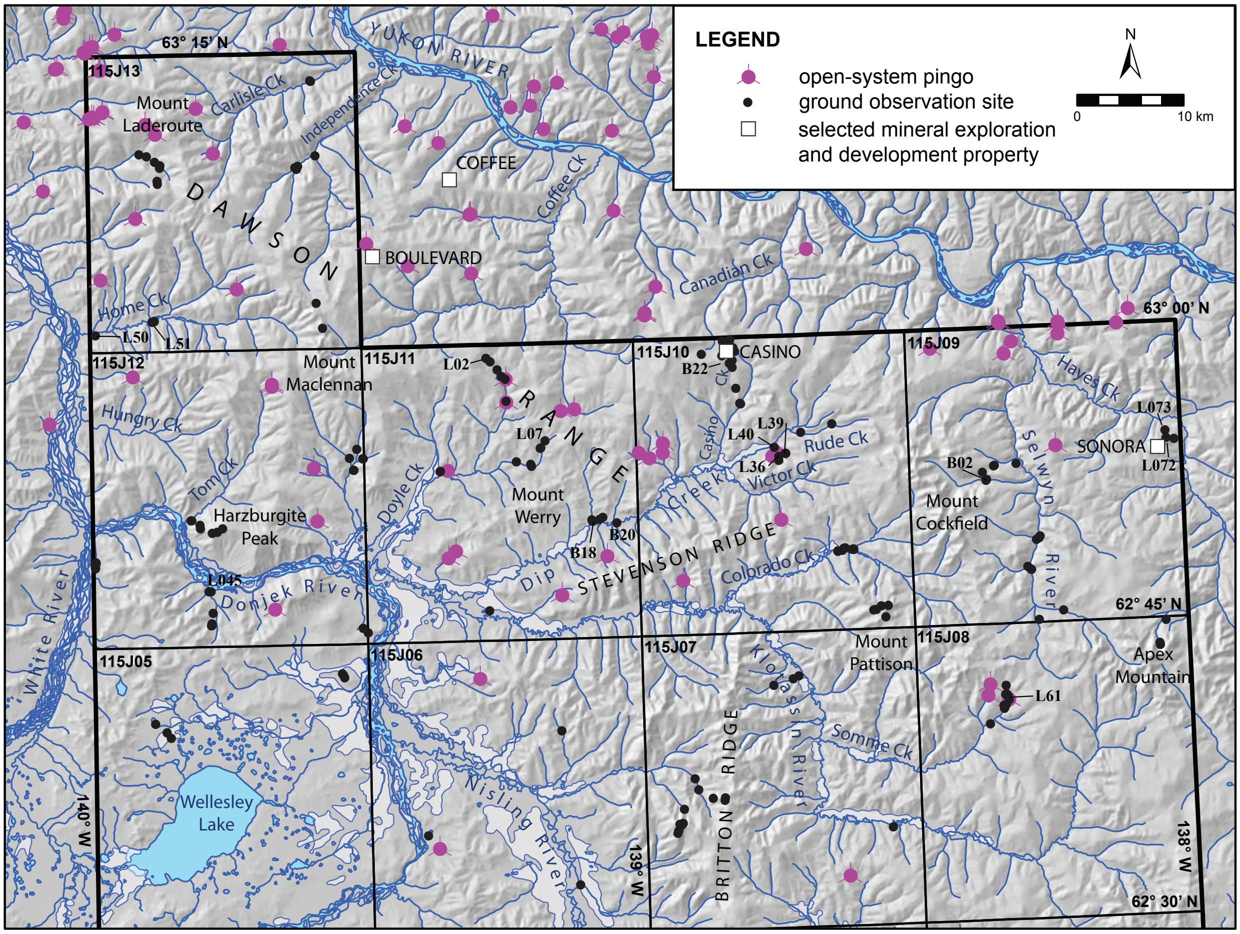

Figure 2. *Location of physiographic features, water bodies, ground observation sites and pingos within the greater study area. Labeled ground observation sites (e.g. L02) are referred to in this report. Relevant mineral exploration properties are also identified.*

BEDROCK GEOLOGY

The bedrock geology of the northern Dawson Range consists of Paleozoic metamorphic rocks of the Yukon-Tanana terrane intruded by Cretaceous and early Cenozoic plutons (Bennett *et al.*, 2010). Regionally, the Cretaceous intrusions are associated with major strike-slip faults that may extend into the Dawson Range, imposing a primary northwest-trending structural trend in the region. Second-order, northeast-trending structures extending up Tom Creek, Doyle Creek and Dip Creek (Murphy *et al.*, 2007) may be associated with extension and local copper-gold mineralization (Bennett *et al.*, 2010).

The northern part of the study area is underlain by the mid-Cretaceous Dawson Range batholith granodiorite (mKW – Whitehorse suite), which was intruded by Late Cretaceous plutons (LKP - Prospector Mountain suite). Upper Cretaceous Carmacks Group volcanics (uKC) are found near Apex Mountain, in the headwaters of the Klotassin River and near the mouth of Nisling River (Fig. 2; Gordey and Makepeace, 2003). Early Cenozoic Skukum/Mount Creedon volcanics outcrop within the Dawson Range batholith and surrounding Britton Ridge which is formed of early Tertiary Nisling Range intrusives (Gordey and Makepeace, 2003). South of Dip Creek, Stevenson Ridge is composed primarily of Paleozoic quartzite and schist of the Yukon-Tanana terrane. Cretaceous mafic volcanics (tuffs and greenstone) and late Paleozoic ultramafics (harzburgite) are found between the mouth of the Donjek River and Mt. Werry (Murphy *et al.*, 2007).

The Dawson Range mineral belt trends northwest through the study area and hosts several copper and gold deposits and prospects (Fig. 1), including:

- White Gold (structurally controlled Au)
- Coffee (Au)
- Boulevard (Au)
- Casino (Au-Cu-Mo-Ag porphyry)
- Sonora Gulch (epithermal/skarn/porphyry Cu-Au-Ag-Mo)
- Revenue (Cu-Mo-Au-Ag-W porphyry)
- Minto (Cu-Au porphyry/IOCG)
- Nucleus (structurally controlled/skarn Cu-Au)

GLACIAL HISTORY

The northern Dawson Range is largely an unglaciated landscape. The only evidence of glacial deposits observed in the study area was on the east side of Mount Cockfield (Figs. 2 and 3). The well developed cirques and end moraine preserved in this area suggests the massif was last glaciated in the late Wisconsin. The glacial limit map of Yukon (Duk-Rodkin, 1999) depicts a series of isolated early Pleistocene ice cap limits on the northern Dawson Range (Fig. 1). While there is evidence of early Pleistocene cirques in this area, we were not able to conclusively identify any depositional glacial landforms. The lack of glacial landform development and the subdued morphology of the cirques suggest this part of the Dawson Range has not been glaciated in over 200 000 years.

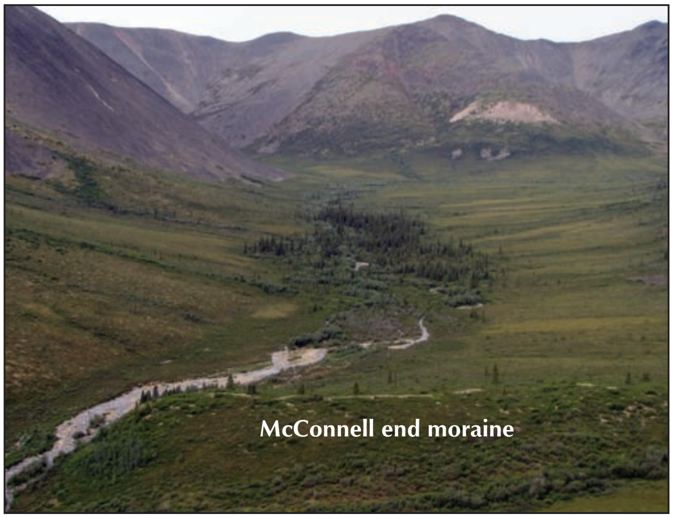

Figure 3. *An alpine glacier end moraine on the east side of Mount Cockfield (see B02 on Figure 2). The moraine is estimated to be McConnell (late Wisconsin) in age based on the distinct sharpness of the ridge crest. View is to the west.*

SURFICIAL GEOLOGY

LOESS

The most widespread glacially derived sediment in the northern Dawson Range is loess, or wind-blown silt. Loess is generated from glaciofluvial flood plains, primarily during glacial and deglacial periods. The Dawson Range has been repeatedly inundated with loess generated from the floodplains of the Donjek and White rivers, and to a lesser extent, the Yukon River (Fig. 2). The northwest orientation of the range provides a perfect barrier for the dominant wind that blows northward from the Pacific. These winds, coupled with katabatic winds generated off the former

St. Elias ice sheet, gathered silt off the Donjek and White river floodplains and deposited it on the upland.

Surficial geology mapping indicates that the loess accumulations are greatest on the southwest-side, or windward side, of the northern Dawson Range. A northeast paleo-wind direction is further supported by a northeast-trending paleo-parabolic dune on the southern flank of the Dawson Range near the Donjek River. The greatest accumulations of loess (>20 m) were observed on tributary valley margins immediately adjacent to the Donjek and White river floodplains (Fig. 4). These deposits are poorly drained and commonly contain permafrost.

WEATHERED BEDROCK

The most common surficial material in the Dawson Range is weathered bedrock (Fig. 5). It varies in texture according to the lithological characteristics of the underlying bedrock, the amount of loess additions to the soil, and the degree of mixing that has occurred between these two material types. Under the current climatic conditions, periglacial and mass wasting processes are the primary means by which bedrock is liberated into the surficial environment. These processes include frost shattering, cryoturbation, solifluction, soil creep and landsliding.

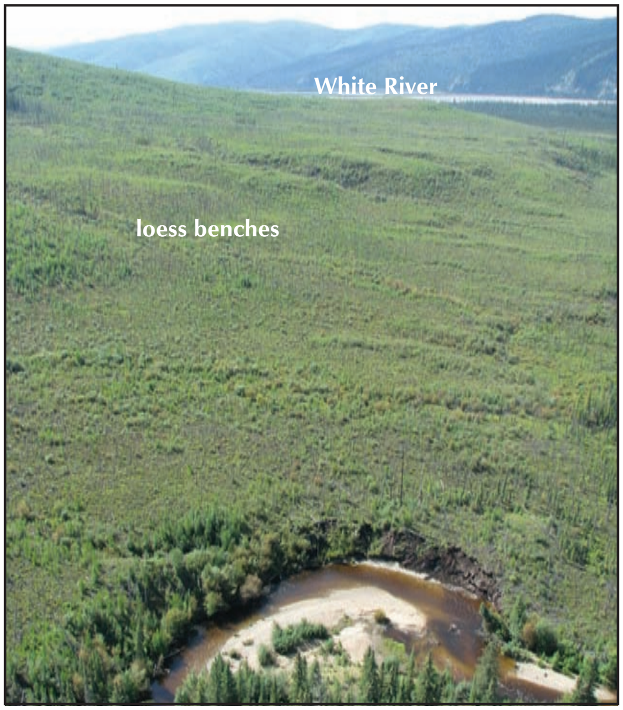

Figure 4. *A view to the southwest over Home Creek; White River is in the background. Thick accumulations (>20 m) of loess (loess benches) are visible along the edge of Home Creek valley.*

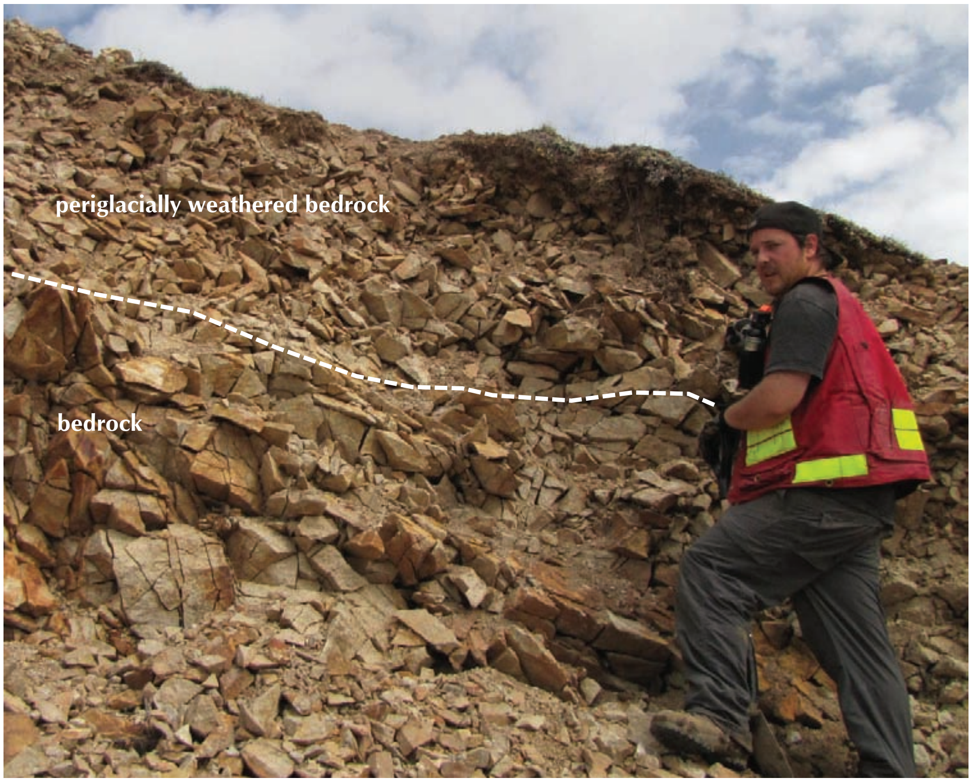

Figure 5. *Photograph from the summit of Palton Hill on the Casino property showing a frost-shattered veneer of weathered bedrock (periglacially weathered) overlying bedrock.*

FLUVIAL DEPOSITS

The texture of alluvium in the study area varies according to stream order. First and second order streams are confined to relatively steep, narrow v-shaped valleys. The alluvium in these settings is dominated by locally derived cobbles and boulders; the loess component and fine sediments are largely washed away. Further downstream in third and fourth order reaches, the floodplains widen and stream energy is reduced. The dominant texture in these active channels is sandy, pebble gravel, and the loess component increases. The buildup of colluvial sediments in the high-order valley bottoms confines most streams and limits lateral erosion of the floodplain.

ORGANIC DEPOSITS

Organic deposits are widespread across the study area. Most organic deposits are less than 30 cm thick; however, thicker deposits may be present on poorly drained, north-facing aspects, and in gently sloping valley bottoms. The organic material consists of partially decomposed fibrous peat containing recognizable macrofossils of willow, sedges and rootlets. Buried organic deposits are common in colluvial deposits that are affected by permafrost processes such as cryoturbation and solifluction.

PERMAFROST

Permafrost is widespread but discontinuous in the northern Dawson Range. Permafrost distribution and character (depth, thickness and ice-content) vary widely with local scale variations in both macro and micro-topography, surface cover and soil texture. It is most prevalent on north-facing slopes and in valley bottoms where thick fine-grained slope toe complexes (interbedded loess, colluvium and peat) and alluvial sediments have accumulated.

A variety of landforms that indicate the presence of permafrost were observed throughout the study area including: thermokarst thaw ponds in broad, higher-order valley bottoms; ice-wedge polygons near the confluence of Dip Creek and Klotassin River; and alpine periglacial features such as solifluction lobes and cryoplanation terraces.

Of particular note was the abundance of open-system pingos in the region. Fifty-seven pingos were mapped in the northern Dawson Range study area and hundreds more are found in the unglaciated terrain to the north (Fig. 2). Pingos are ice-cored conical mounds; in the study area, they have dimensions on the order of 10-20 m in height and 100-200 m in width. Hughes (1969) suggested that the distribution of open-system pingos in central Yukon is controlled by topography and permafrost thickness, as well as the appropriate configuration of discontinuous permafrost that allows both groundwater recharge on unfrozen slopes and confinement of artesian pressures beneath frozen valley bottoms.

The pingos in the northern Dawson Range are typically located at the margin of narrow valley floors (Figs. 2 and 6). Most of the pingos have collapse craters suggesting that their ice cores have since thawed. The pingos have developed in a variety of sediment types including fine-grained loess and alluvium, coarser grained grus (grit to pebble-size weathered intrusive fragments), and even bedrock. Establishing the age of pingo formation and collapse was beyond the scope of this study, but warrants further investigation as these landforms are regarded as important habitat islands.

Frost tables were observed in soil pits and stream cut bank exposures at 42 field sites that were visited between July 7 and July 24, 2010. Frost table depths varied between 20 and 170 cm below the ground surface, but were generally less than 1 m. Active layer thicknesses (depth to permafrost table), measured at the end of the summer thaw season, are expected to be of a similar depth or slightly deeper. The frost table was commonly as shallow as 20-40 cm where surface organic cover exceeded 10 cm in thickness.

While permafrost thickness likely varies considerably with topographic position and aspect, several larger subsurface exposures revealed minimum permafrost thicknesses on the order of 10 m in valley bottoms. For example, 12 m of permafrost was exposed in a Sonora Gulch placer excavation (L73); 7 m was exposed in a cut bank on a tributary to the Donjek River (L45); and 9 m was exposed in a Home Creek cut bank (L51).

Volumetric ice contents were visually estimated in the field and were highly variable. Ice contents were generally less than 20% and consisted of thin veins, particle coatings and pore ice. Higher ice contents (up to 50%) were observed in valley bottoms and on mid to upper slopes where groundwater convergence occurred. Thick massive ice lenses consisting of buried aufeis were commonly observed in valley bottoms of low-order drainages. Ice wedges were also observed in a Home Creek cut bank. Clearing or disturbance of organic cover in these areas may lead to rapid thaw and destabilization of ice-rich ground.

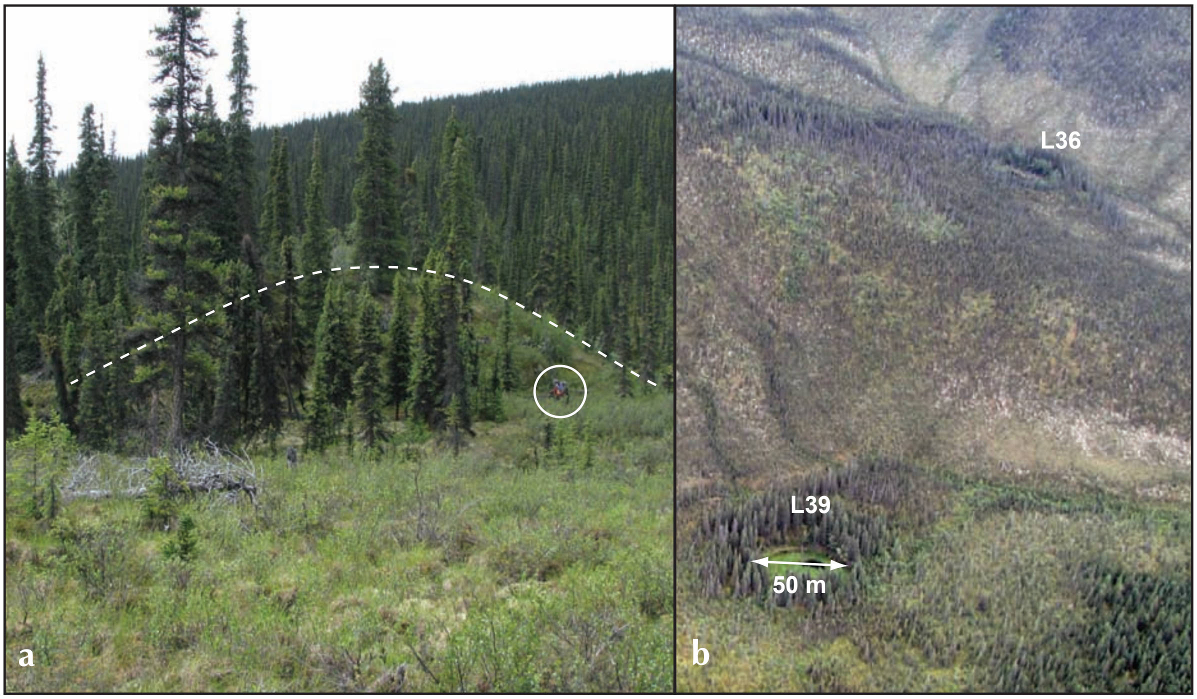

Figure 6. *Both uncollapsed* ***(a)*** *and collapsed* ***(b)*** *open-system pingos were observed in the study area. The uncollapsed pingo is in Somme Creek (L61; Fig. 2) and formed in weathered basalt. The pingo is 5 m high and 45 m in diameter. Note the person circled for scale in Fig. 6a. The collapsed pingos are in a tributary to Rude Creek (L36 and L39; Fig. 2) and both have formed in a silty, colluvial diamicton.*

SOIL FORMATION

The term 'soil' can have different meanings depending on its user. For example, in the mineral exploration industry, 'soil sample' is common terminology to describe a near surface sample of unconsolidated sediment. For the purposes of this study, we define a soil sample as the weathered component of parent material that has been altered by chemical, biological, and physical weathering. In the northern Dawson Range, this alteration occurs mainly through decomposition of organic material, translocation of organic matter and silt, enrichment in iron and aluminum oxides and physical weathering by permafrost and periglacial processes. All of these processes, and the extent to which they develop, are affected by topographic position. Lastly, soil properties are affected by the presence of multiple parent materials. In the northern Dawson Range, the most common parent materials include colluvium, alluvium and loess.

General soil horizon characteristics, such as colour, thickness and structure were described based on observations made in the field at hand-dug pits and natural exposures. Due to the cold, semi-arid climate of the region, physical weathering processes like cryoturbation tend to override most other soil forming processes.

Residual soils that formed directly from weathered bedrock contain the least complex parent materials observed in the study area. In the northern Dawson Range, these soils are restricted to flat landscapes typically found on mountain summits and ridges. Detailed soil analyses of high-elevation residual soils was not completed as part of this study; however, recent investigations by Dampier (2010) and Dampier *et al.* (2009) near the southern Dawson Range did characterize the genesis of high-elevation granitic soils. They concluded that periglacial activity, namely cryoturbation, is the most important process affecting upland soils. Chemical analyses indicated that little soil development has occurred, although evidence of alteration of primary minerals demonstrated some chemical weathering. This was present in the form of secondary clay minerals such as kaolinite, vermiculite and minor smectite.

Soil development on slopes is primarily affected by insolation related to aspect (Bond and Sanborn, 2006). On well-drained south-facing slopes, soil horizons are well defined and have not been disrupted by cryoturbation (Fig. 7). The organic horizons and A horizon (incorporated decomposed organic matter) are between 4 and 10 cm thick. The B horizon is emphasized by a zone of iron oxidation that extends up to a depth of 25 cm. The

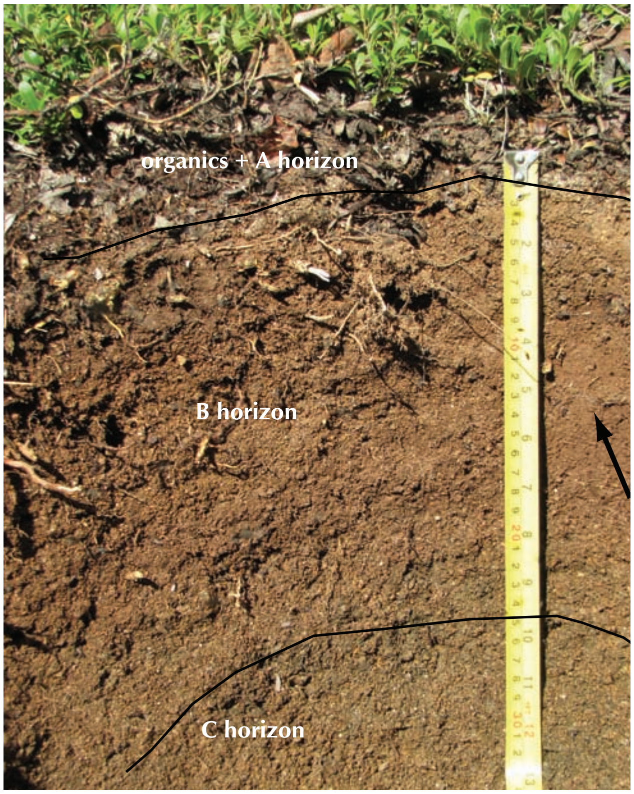

Figure 7. *Soil profile on unfrozen, well-drained bedrock ridge near Dip Creek (B18; Fig. 2). Note the thin surface organic horizon and strongly oxidized colour of the B horizon. The B horizon is siltier and contains fewer coarse fragments (see arrow) compared to the underlying C horizon.*

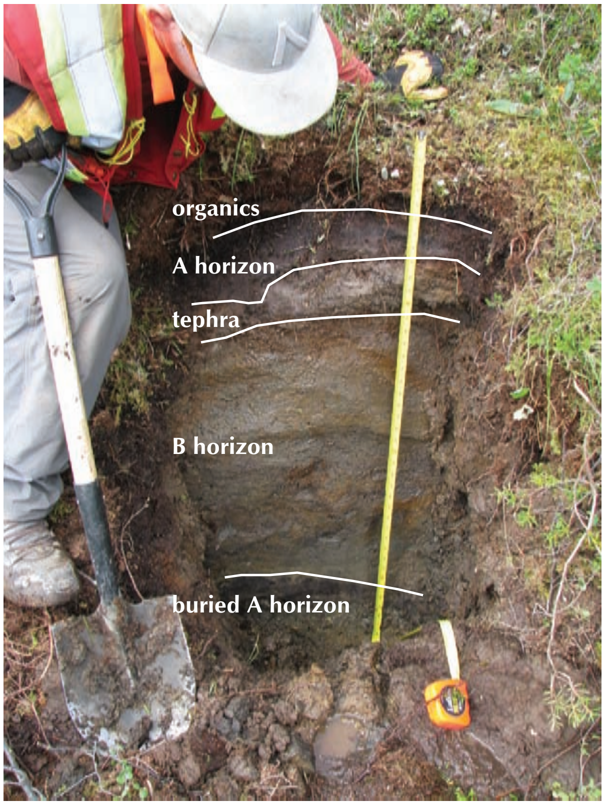

Figure 8. *Partially thawed Cryosolic soil on Casino property. Note the thick surface organic horizon and absence of oxidized colours. The buried A horizon at the base of the soil pit may have been created by solifluction and/or cryoturbation. The permafrost table is at the contact between the A horizon and the tephra (22 cm depth).*

oxidation often occurs within the loess veneer, although it may extend into the underlying weathered bedrock colluvium. Silt caps are present on the tops of clasts, and build up gradually as silt in suspension is transported downward through the soil horizons via percolating groundwater. These soils are classified as Brunisols based on the absence of permafrost, limited accumulation of organic matter, and strong oxidized colours.

On north-facing slopes, soil development is affected by widespread cryoturbation and near-surface permafrost. Cryoturbation may extend to a depth of 75 cm, mixing both the loess and weathered bedrock parent materials (Smith *et al.*, 2009). Cold soil temperatures reduce the rate of organic matter decomposition, resulting in a surface horizon of partially decomposed organic matter up to 30 cm thick (Fig. 8). The organic horizon insulates the mineral soil and slows the rate of weathering and soil development. As a result, evidence of B horizon weathering is limited to a thickness of 0-10 cm. These soils are classified as Cryosols based on the presence of permafrost.

SURFICIAL GEOLOGY LANDSCAPE MODEL AND EXPLORATION GEOCHEMISTRY SUITABILITY

To summarize the distribution of surficial materials in the northern Dawson Range, an idealized cross-section was developed (Fig. 9). Each of the landscape positions and their suitability for exploration geochemistry are discussed below.

SUMMITS AND RIDGE TOPS

On mountain summits and ridge tops, limited movement of the weathered bedrock has occurred, especially on gentle slopes such as those underlain by the Dawson Range batholith. Tors are common on the batholith and proximity to these bedrock features signifies limited transport of the weathered bedrock sediment (Figs. 9 and 10). These weathered bedrock deposits are typically <1 m in thickness and may be overlain by a veneer of

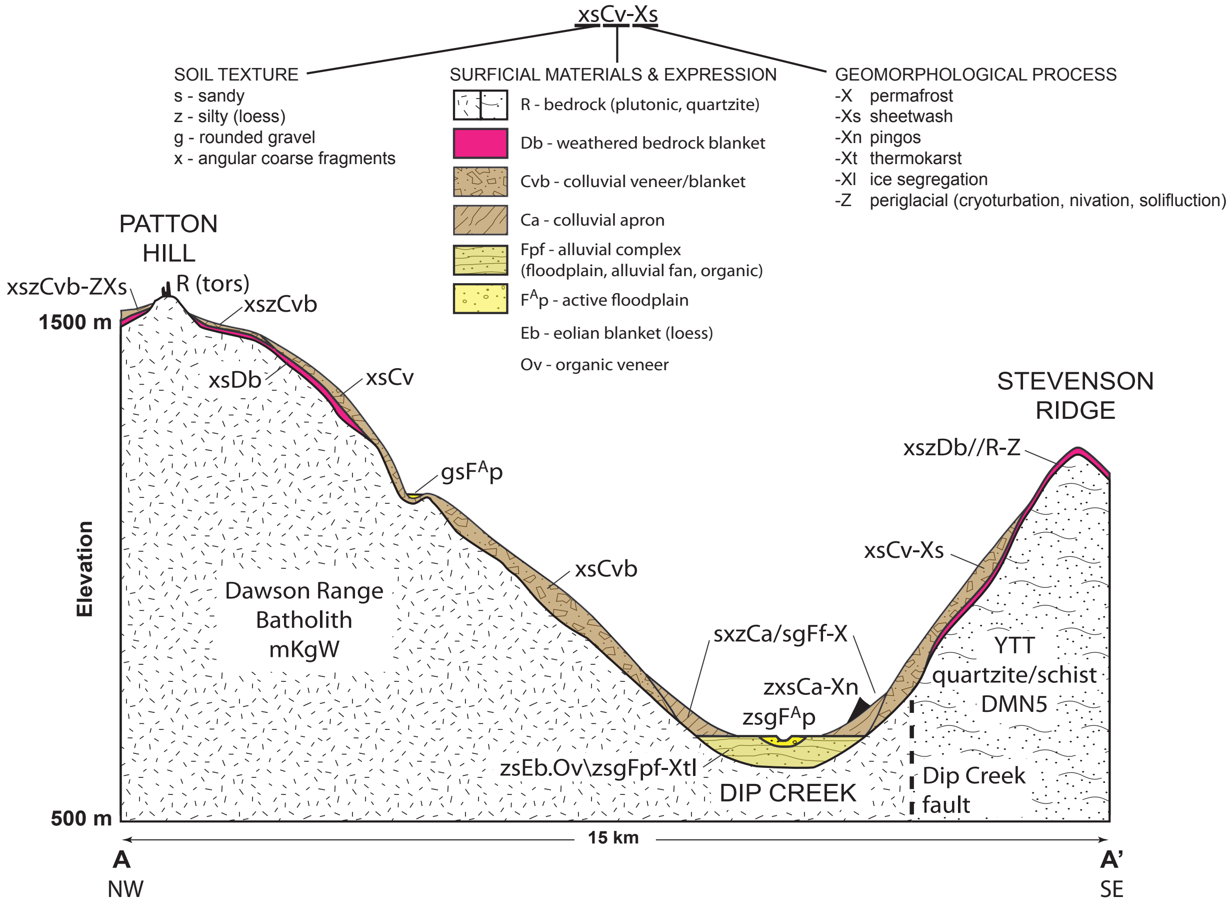

Figure 9. An idealized cross-section of the surficial geology across Dip Creek in the northern Dawson Range. This cross-section also illustrates the terrain classification system used for mapping the surficial geology. Regional bedrock map units (DMN5 and mKgW) from Gordey and Makepeace, 2003.

loess (10-20 cm thick) if the site is relatively flat. The loess will be incorporated in the soil profile if cryoturbation has occurred (Dampier *et al.*, 2009; Bond and Sanborn, 2006). Common landforms that signify cryoturbation in alpine environments include sorted stone polygons and mud boils. Soil geochemical samples should be derived from a minimum of 30 cm depth to avoid the loess-enriched soil horizons.

UPPER SLOPES

Immediately downslope from the summit environments are the upper slopes. These landscape environments are spatially extensive over the Dawson Range batholith where much of the landscape has broad, convex, low-angle slopes (Figs. 9 and 11). The primary surficial material on these slopes consists of colluvial veneers (<1 m thick) and blankets (>1 m thick) of transported weathered bedrock fragments. The transport distance of the fragments decreases with depth, although cryoturbation and solifluction can complicate this pattern by increased mixing of parent materials.

The loess enrichment on these slope positions can be high due to the low slope angles and limited surface erosion. A good example of this was documented on the Casino property. At this site, the intrusive bedrock weathers into coarse angular boulders that become entrained into the upper slope colluvium. Less than 1 km down slope from the summit, on a gentle slope (<10°), the upper 100 cm of the colluvium matrix consisted of ~80% silt and clay based on field estimates (Fig. 11). The matrix of this colluvium is surprisingly fine, given the sandy texture typically associated with weathered granodiorite. For this reason, we suspect that most of the silt was derived from loess deposits. In order to minimize the loess content in soil samples, and potential masking of the weathered bedrock geochemistry, it is recommended to target the sandier components of the colluvium for assaying (Bond and Sanborn, 2006). Soil sampling on upper slopes should therefore be restricted to depths greater than 50 cm.

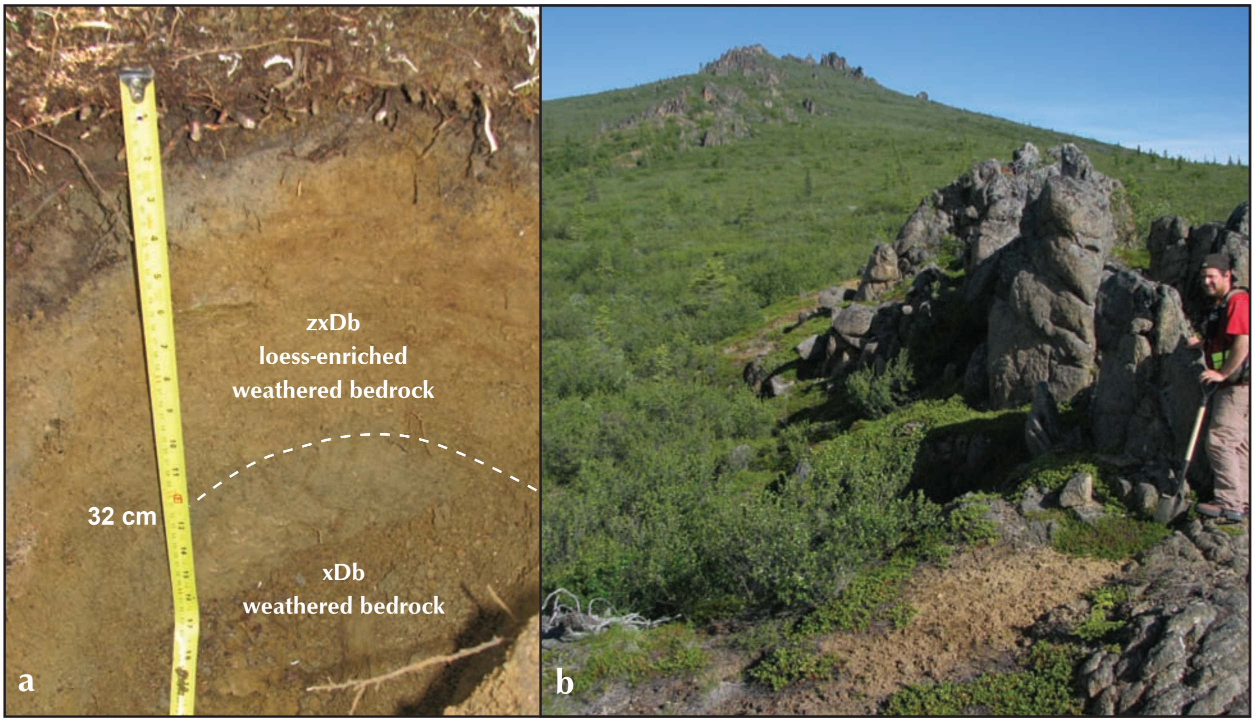

Figure 10. (a) *A typical soil profile found near a tor in the Dawson Range summit environment in the study area (L02; Fig. 2). The surficial material exposed in the soil pit consists of loess-enriched weathered bedrock overlying weathered bedrock. For definitions of the classification codes refer to Figure 9.* ***(b)*** *Granodiorite tors are a common summit feature within the Dawson Range batholith.*

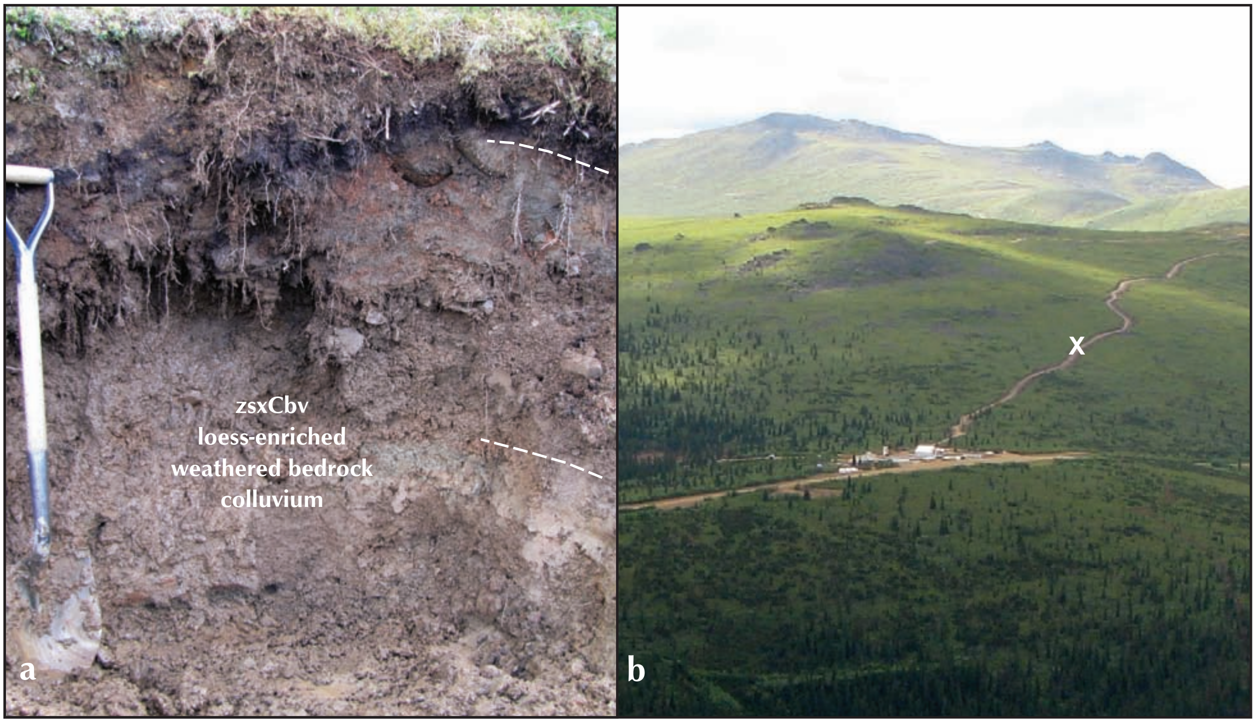

Figure 11. (a) *A soil pit illustrating the upper slope position surficial geology (B22; Fig. 2). The surficial material exposed in the soil pit consists of loess-enriched weathered bedrock colluvium that is cryoturbated. The silt content can be as high as 80% in the upper parts of this unit. The zone primarily affected by cryoturbation is identified between the dashed lines.* ***(b)*** *An aerial view illustrating the upper slope position near the Casino camp (the "x" marks the location of soil pit in Fig. 11a).*

MID-SLOPES

On the mid-slope positions, the slope angles increase into the first-order drainage basins (Fig.12). Similar to the upper slopes, these slopes are mantled with weathered bedrock colluvium (Fig. 9). The colluvium has a stratified appearance, which is accentuated when there are colour variations in the upslope bedrock lithologies. Similar to the upper slope position, the distance of transport of the weathered bedrock fragments decreases with depth (Bond and Sanborn, 2006).

Solifluction lobes are common on these slopes, especially above tree-line. A detailed examination of alpine solifluction lobes on Mount Pattison revealed a decrease in silt content with depth. The internal composition of the lobes consisted primarily of coarse bedrock fragments and little matrix. It appears that much of the movement occurs through deformation within the basal coarse fragment layer.

Loess enrichment is generally lower on mid-slopes because erosion is more active. Some of the loess will get incorporated into the B horizons during the soil creep process, but a significant amount is transported into the valley bottom. Soil geochemical data are more reliable if sampling occurs at a depth that is greater than 30 cm; however, it is important to account for greater transport distances when interpreting the geochemical data. In addition, large geochemical variations can occur between the colluvial layers depending on the lithological variations and presence of mineralization in the upslope bedrock (Bond and Sanborn, 2006).

LOWER SLOPE COLLUVIAL APRONS

At the base of slopes, significant deposits of colluvial sediment and organic material have accumulated (Figs. 9 and 13). The term colluvial apron is used to describe these deposits because they form a near continuous wedge of sediment at the transition from the hill slopes to the valley bottoms. The colluvial aprons consist mainly of retransported loess mixed with slopewash sediment, which consists of sand and granules that have been carried down slope by water seeping above the permafrost table. Lenses of coarser sediment are common at the base of steeper slopes. In the northern Dawson Range, these landforms cover a significant area, especially along the margins of third and fourth-order valley bottoms. In narrower valleys, the aprons tend to be smaller due to fluvial erosion. Retransported loess

Figure 12. ***(a)*** *A surficial sediment profile showing the stratified weathered bedrock colluvium that is typical on mid-slope topographic positions (L072; Fig. 2).* ***(b)*** *Aerial view illustrating the mid-slope position in Sonora Gulch. The "X" marks the location of the surficial geology profile.*

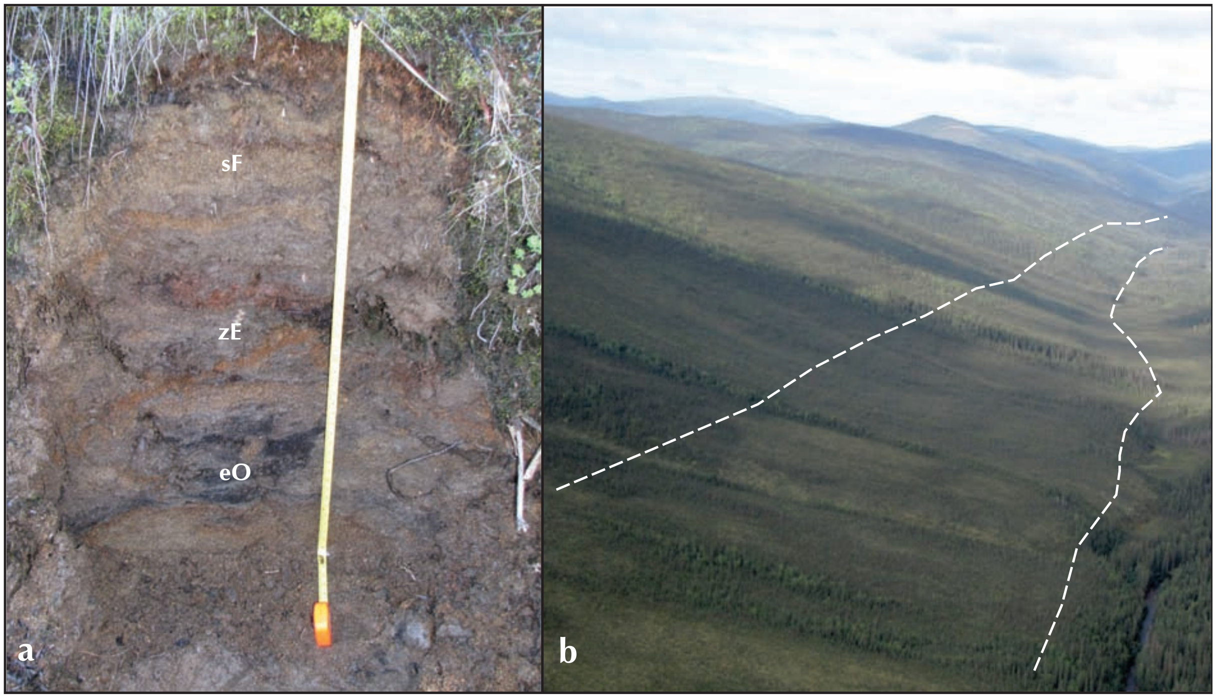

Figure 13. ***(a)*** *Surficial sediment profile of typical colluvial apron deposits consisting of retransported loess (zE) mixed with sandy slopewash sediment (sF) and organic matter (eO).* ***(b)*** *Aerial landscape view of colluvial apron in lower slope position (between dashed lines).*

is the primary sediment type in these landforms and consequently their suitability for exploration geochemistry is low. Ice-rich permafrost is also common in these landforms because of their lower slope position and high silt and organic content, which impedes drainage.

VALLEY BOTTOMS

As described previously, the texture of fluvial deposits vary according to stream order. Alluvium is the main surficial material in valley bottoms of low-order streams, whereas mixed alluvium and colluvium deposits are common in the valley bottoms of broad, high-order streams (Fig. 14). The alluvium in the third and fourth-order valleys is finer and consists of sandy pebble gravel that is typically overlain by silt and widespread organics. Permafrost is continuous in these environments.

Exceptions to this observation include direct tributaries to the Yukon River that have undergone a base-level change. This change has increased stream energy and erosion by increasing the stream gradients and reducing the floodplain width. Fluvial sediment in these drainages is coarse and loess deposits are restricted to blankets on fluvial terraces, or aprons at the base of north-facing slopes. A second exception was found in the valleys on the north side of Stevenson Ridge. Large gravelly fluvial fans originating from Stevenson Ridge are exposed in cut banks of Dip Creek (B20; Fig. 2). Gravel channels were also noted on the surface of these landforms suggesting active channel avulsion. In terms of aggregate use, the Stevenson Ridge fluvial fans are strategically located for future development in the region.

Mapping the textural variability of fluvial sediment and the relationship to valley morphology is important in stream sediment geochemistry applications. Most stream sediment geochemistry projects assay the silt fraction of the alluvium. This is problematic in the study area because loess is so pervasive. To improve the reliability of stream sediment geochemical exploration, sampling should occur in narrow valleys with high energy streams where the loess content is low. In addition, experimenting with excluding the silt fraction (-230 mesh) from analysis could improve reliability. If this technique is employed, it is important to remember that assay results should not be compared to other surveys where the silt (and clay) fractions were included.

The landscape criteria for obtaining reliable stream sediment samples can also be applied to the regional stream sediment database (RGS). A quick evaluation of the results for arsenic in the study area show that higher values are preferentially found in the first and second

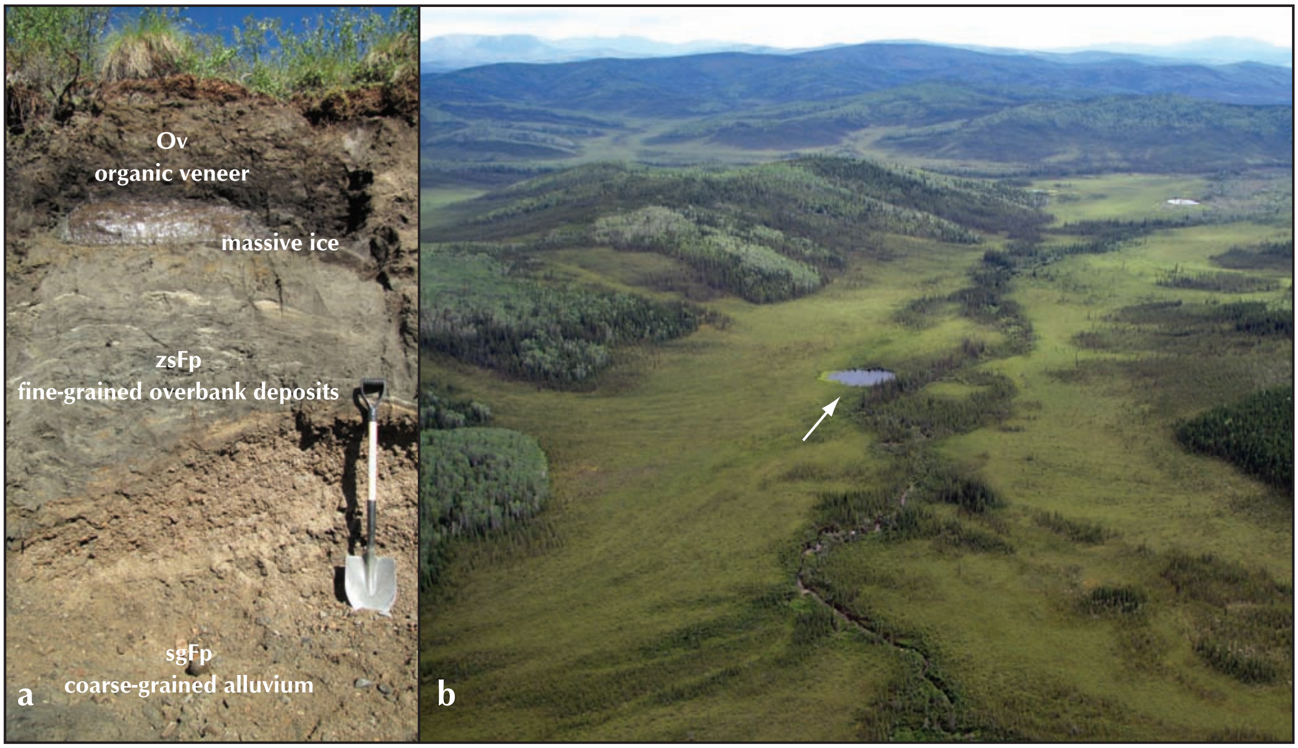

Figure 14. ***(a)*** *Surficial stratigraphic profile of typical fluvial sediment in third and fourth-order valley bottoms on the south side of the Dawson Range (B18; Fig. 2). Permafrost is common within 30 cm of ground surface.* ***(b)*** *Aerial landscape view of the poorly drained third-order valley bottom environments found on the south side of the Dawson Range. A thermokarst thaw pond is denoted by the arrow.*

order stream reaches. Anomalies also occur at lower elevations in tributaries to the Yukon River, possibly due to the Pleistocene base-level change. On the south side of the Dawson Range, there are virtually no anomalies in the third or fourth order streams. While this pattern may reflect bedrock geochemistry, it is our impression that it is more likely a function of loess content. In order to prospect the higher-order, low-gradient streams, it is recommended to target coarser alluvium for assaying, apply heavy mineral sampling, or rely strictly on soil geochemistry from adjacent uplands.

SUMMARY

Surficial geology mapping in the northern Dawson Range has emphasized the role that topography and periglacial processes play in affecting unconsolidated material in sub-Arctic unglaciated uplands. The surficial material distribution patterns are somewhat repetitive across the landscape; however, the introduction of loess from nearby braided rivers, and base-level changes in the Yukon River can add local complexities. In terms of mineral exploration, soil geochemical exploration programs need to recognize the distribution and intensity of cryoturbation in order to effectively interpret geochemical data. Stream sediment geochemistry is affected by the ability of streams to effectively mobilize colluvium that reaches the valley bottom. As a result, valley width and gradient, which have a direct relationship to stream order, are important landscape characteristics to consider when planning new stream geochemical surveys or interpreting old data.

Finally, the distribution and character of permafrost in the Dawson Range is affected by the texture of the surficial material, slope aspect and topographic position. Successful development in the northern Dawson Range will require a good understanding of its distribution and character in order to avoid destabilization of ice-rich ground.

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